future. On the basis of a balanced deal in which both humans and animals learn from each other's experience and help each other maintain a life-enhancing biosphere, an ethical application of the internet of animals appears possible. On the scale of individual animals, one also has to consider that all tagging technology will place a burden on the animal in question and may reduce its fitness. Whether the purpose is understanding or conservation, there is a cost–benefit analysis to be made, and the benefit is likely to be greater when the fitness cost to the animal is smaller, such that the effect on its natural behaviour ultimately becomes negligibly small. Thanks to the ongoing progress in the miniaturisation of communications technology and the optimisation of solar-powered devices, tags are likely to become less and less invasive, thus shifting the balance more and more in favour of the benefits.

It is already routine procedure to monitor wildlife via satellites, and affordable drones have in recent years also found an important role in ecology and conservation research (Curr. Biol. (2014) *24*, R629–R632). The ICARUS (International Cooperation for Animal Research Using Space) project, a joint venture of the German and Russian space agencies, will soon add a significant new tool to the tracking repertoire, namely the International Space Station, ISS. The use of the space station will enable researchers to track the moves of many thousands of small animals, such as migrating songbirds equipped with a miniaturised radio chip, simultaneously and on a large scale.

Launched in 2012, the project is due to start recording data in the spring of 2016, when the communications unit arrives at the ISS. The space-based tracking will address important questions on a global scale, including the distribution of zoonoses like avian influenza, responses of the biosphere to climate change, and early warning of natural disasters. It will, quite literally, take the monitoring and understanding of animal movements to a whole new level.

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Book review

Nature's nature and the place of non-native species

Daniel Simberloff

The New Wild – Why Invasive Species Will Be Nature's Salvation
Fred Pearce
(Beacon Press, Boston, US; 2015)
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Every corner of the globe except Antarctica has its high-profile invasive species from elsewhere — animals like the small Indian mongoose in the West Indies, the Burmese python in Florida, and the Argentine ant in Europe and North America; plants like Brazilian pepper in North America and Japanese knotweed in Europe; microbes like Dutch elm disease and West Nile virus in North America. In 1958 English ecologist Charles Elton first pointed out that these local and regional invasions are one of the great forces changing the biology of the earth today, along with climate change and land use modification, in *The Ecology of Invasions by Animals and Plants*, and in the 1980s a project of the international Scientific Committee on Problems of the Environment helped spawn a burgeoning discipline of invasion biology. Invasion biologists sought to understand why some species became highly invasive while others were innocuous, why some regions seemed particularly prone to ecological disruption by non-native species, and how such information could aid prevention of invasions and management of invasive species so as to minimize their impact. New scientific journals such as *Biological Invasions* and *Neobiota* served as platforms for research on invasive species, and several dozen books have been published since the 1980s on the general phenomenon of invasion or the details of specific invasions.

During the early rise of invasion biology, a small number of critics lambasted the entire enterprise [1]. These were mostly social scientists — anthropologists, historians, philosophers, sociologists — and the chief complaint was that the field was tainted with xenophobia: in this view, the non-native newcomers were despised simply because they were not native. This literature amounted to a social construction of the science, with little or no attention paid to the actual ecological or economic impacts of the non-native species. More recently, a small but vocal group of biologists have joined the fray, adding to the charge of xenophobia the claims that most non-native species are relatively harmless and that, in the face of globalized trade and travel, we can't do much about them anyway, so management efforts are largely wasted [2].

Fred Pearce's *The New Wild* is the first book advancing this argument for a lay audience. It is a shock, beginning with its title. Pearce, an environmental journalist, argues that, far from being the scourge depicted by both scientists and popular media, legendary invaders — salt cedar, the zebra mussel, Japanese knotweed, the Nile perch, the killer alga, kudzu, cheatgrass, *Rhododendron ponticum*, rinderpest — are not only not so bad but actually benefit conservation. The standard story (Pearce calls it "orthodoxy") is all wrong! Government programs to control invaders are misguided, as are WWF International, the IUCN, Birdlife International, and other conservation NGOs who militate against non-native species, and so is the Convention on Biological Diversity for targeting them. The heralded new European Union Regulation 1143/2014 to ban the possession, transport, or sale of certain alien invasive species is "ill-considered" (p. 119).

How were the public and its policymakers led so badly astray? Pearce places much of the blame on scientists, "Scientists, starting with Elton, should take considerable responsibility for building public sentiment against anything alien and for giving respectability to some unpleasantly xenophobic language on the issue from environmental groups, as well as ill-considered legislation," (p. 119). Conservationists are also in the dock, "Conservationists need to take a hard look at themselves and their priorities...they must put aside their old certainties and ditch their obsessions with lost causes, discredited theories, and mythical pristine ecosystems," (p. 176). Ouch!

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A substantial reason for the disconnect between the standard story and Pearce's almost diametrically opposite one is his conception of 'nature'. He never defines it explicitly, but it is apparent from context that nature for him is whatever species happen to be at a site. Thus, "nature's resilience in the face of the considerable damage humans have done" (p. xi) resides in the fact that some species are present anywhere, even in a parking lot. The puzzling contentions that alien species are "nature at its best" (p. 151) and that "nature overall is doing fine" (p. 175) around Chernobyl and can "bounce back" (p. xiv) similarly make sense as value judgments if nature is simply whatever species are present. His claim that "nature never goes back" (p. 193) remains murky. The proclamation that alien species are "the shot in the arm that real nature needs" (p. xiv) is less mysterious given Pearce's conception of nature plus his love of local biodiversity (species richness, in this book) for its own sake, no matter which species constitute it: "Most alien species add to local diversity and enrich species-poor ecosystems," (p. 18). They "add color and variety to the landscape. Thanks to them, the biodiversity of the British Isles is probably greater than it has ever been," (p. 79). He claims the same for that of New Zealand birds, neglecting to note that 20-odd native New Zealand birds went extinct because of introduced rats, cats, and mustelids, sometimes in combination with hunting or land use changes. Nor does he mention that all five species of kiwi, the national bird, are threatened with extinction by these predators.

If one takes this view of nature and local biodiversity, then how non-native species should be viewed and managed and what conservation should conserve become questions of values, including ethical and aesthetic values, and most of the scientific and conservation literature has, as Pearce often laments, taken a rather different view from his. The science, even before Elton, has largely focused on the impact of non-native species on native species and on ecosystems. Pearce, by contrast, strives to show how non-native species often pilloried for harming native species and ecosystems are getting a bum rap — he believes they are usually blameless, "passengers" of anthropogenic change rather than "drivers," and often even help native species. His effort is plagued by poor scholarship of two sorts.

The first is presenting just one side — usually the minority side — of a complex story. Time and again, a wealth of sound research on the impact of non-natives is ignored in favor of one report that supports Pearce's narrative. An example is his take on Japanese knotweed (Figure 1), which Great Britain's Environment Agency terms "indisputably the UK's most aggressive, destructive and invasive plant." Pearce argues that it is not an environmental threat because it thrives in disturbed areas, often in urban settings. His sole reference that Japanese knotweed is not an environmental threat is an unpublished personal communication. The only scientific paper he cites on knotweed [3] does not downplay the threat and in fact raises the prospect that hybrids of Japanese knotweed pose a new, even more substantial menace. Meanwhile, many papers (examples include Richards *et al.* [4] and references therein) are ignored that detail environmental impacts of Japanese knotweed and its hybrids, impacts not confined to urban or disturbed areas. Similarly, citing only the puzzling crash of the Argentine ant in New Zealand, Pearce asserts that "while invader ant populations boom, they usually bust," (p. 15). There is, in fact, no other scientific report of a major ant invader substantially declining. For all five invasive ant species that are probably the most widespread and abundant, extensive research shows lasting ecological impacts [5], and among recent invasions by formerly restricted species (e.g., the 'European fire ant', tawny raspberry ant, and Asian needle ant in the United States), none show signs of abating.

The second scholarship problem is repeated failure to know, properly interpret, or acknowledge scientific literature. For instance, Pearce argues that most eradications of non-native species create unintended consequences worse than those of the eradication target, citing Elton's classic book to the effect that eradication of the muskrat in Great Britain contributed to a drastic decline of the water vole.

Figure 1. Invasive non-native species in Great Britain.
Top, Japanese knotweed, which colonizes roadsides and urban open spaces, but also streamsides and river banks in rural areas, forming dense masses that exclude other vegetation. (Image: Wikimedia Commons.) Bottom, American mink, voracious predator of mammal, bird, fish, and invertebrate prey, implicated in the precipitous decline of the water vole. (Image: Wikimedia Commons.)

He adds that the American mink (Figure 1) was subsequently falsely accused of having contributed to the decline that was actually caused by the eradication project. In fact, Elton says no such thing, only that 2,305 voles were killed. Further, the evidence that the mink, along with habitat fragmentation, is truly a leading threat to the vole is overwhelming and prominently published in the scientific literature [6]. Pearce says that a third of California's native butterflies depend on non-native plants for food. His cited reference [7] does not say this, stating simply that 34% of them feed or oviposit on non-native plants at least occasionally. For some that oviposit, it is a trap, as the new host is toxic to the caterpillars.

Pearce claims conservationists are "confused" about the coqui (a Puerto Rican frog) because the IUCN lists it among 100 of the worst invasive species owing to its impacts in Hawaii, while also listing it on its red list of threatened species, ostensibly

because “its only ‘native’ habitat is a small fragment of old Puerto Rican forest” (p. 156). In fact, the IUCN lists it in its “least concern” category, because “although there have been some declines in montane populations (probably at a rate of less than 30% over ten years), perhaps due to a combination of climate change and/or chytridiomycosis, it is an extremely abundant species, it is found in disturbed habitats, and lowland populations appear to be unaffected,” [8].

Pearce cites a 2002 report on a non-native vine flourishing after eradication of goats and pigs from Sarigan Island, proclaiming “it has now run riot and covers most of the island,” (p. 94). He does not cite the same author’s 2011 follow-up showing that native forest cover has increased greatly, most native animal and plant species have increased in abundance, and the success of the project has inspired planning for a similar eradication on another island [9]. Casting doubt on a classic 1987 paper suggesting that *Morella faya*, an introduced nitrogen-fixing plant in Hawaii, will cause major ecosystem changes, Pearce is unable to find subsequent data: “Nobody, it seems, has bothered to research the question” (p. 13). A Google Scholar search would have shown much subsequent research, including demonstration of major changes in biogeochemical cycles [10].

Pearce rehashes the well-known story of the Nazis’ loathing of introduced plants, and though he says “nobody would accuse today’s environmentalists of being secret fascists, this political legacy is...disquieting.” To whom, and why? Actually, in a rather similar book, *Invasion Biology: Critique of a Pseudoscience*, seed merchant David I. Theodoropoulos charges invasion scientists with being xenophobes, and journalist Michael Pollan strongly hints that native garden enthusiasts are motivated by this sentiment [11]. Pearce does not cite detailed examinations that consider, then reject this accusation [1]. Pearce deplores “militaristic and xenophobic metaphors” (p. 105) that “demonize” non-native species, but he is not averse to analogous metaphors demonizing invasion biologists, managers, and conservationists, terming the project to eradicate introduced rats from South Georgia Island “Paulsen’s pogrom,” (p. 91) and entitling a chapter about the futility and wrong-headedness of attempting to remove non-native species “Ecological Cleansing.” Surely it is futile to admonish both journalists and scientists not to use metaphors that they see as clever attention-grabbers.

The New Wild closely tracks one message of journalist Emma Marris, whose *Rambunctious Garden: Saving Nature in a Post-Wild World* Pearce cites. Marris uses virtually the same arguments (e.g., espousal of novel ecosystems featuring non-native species, favoring increased local biodiversity no matter its components, assertion that an undefined ‘nature’ is robust and resilient) and even a similar manifesto-like title [12]; Pearce’s main addition is a wealth of often flawed or mischaracterized examples to buttress his key points. Both Pearce and Marris see as a key support for their views what they depict as the revolutionary recent replacement of a “balance of nature” worldview by one of nature in flux. In fact, scientists discarded the idea of a robust balance of nature long ago [13], and it plays no substantial role in the rise of invasion biology and management, where the focus is on specific impacts of specific invaders. Here Pearce does acknowledge a difficulty for his view, admitting that species introductions may spread slowly even if inexorably and ultimately widely, and impacts may not occur or be recognized for decades. In fact, extinction of native species may take even longer — centuries or millennia until the last individual disappears. Pearce suggests that hybridization may create at least as many new species as will go extinct because of invasions; as he says, only time will tell.

The book abounds with examples of non-native species — some famously invasive — that somehow benefit Pearce’s conception of nature. It is surely worth noting what seem to be beneficial effects of introductions. However, this should be in the context of the full gamut of impacts, pluses as well as minuses. Pearce fails repeatedly on this score. For cheatgrass, for instance, “Americans probably have reason to be thankful” (p. 59), based on his questionable assertion that it stemmed soil erosion and desertification. No mention of the massive cheatgrass-fueled fires that have ravaged millions of acres of rangelands in the West, devastating native grassland and sagebrush communities and their many charismatic species, such as the sage grouse. Zebra mussels are a boon in North America because their filtration clarifies invaded waters and several fishes eat it — it “seems perverse” to worry about it; it’s just part of “new ecological environment...with its own checks and balances” (p. 62). No mention that the zebra mussel threatens many native mussel species by smothering them and outcompeting them for food.

The New Wild bristles throughout with puzzlement, frustration, and anger at what Pearce sees as the obstinacy of scientists, conservationists, NGOs, and governments to jump onto the new bandwagon. “Ecologists are tying themselves in knots,” (p. 156), and “most conservationists have been reluctant to open their eyes,” (p. 156). Whereas Theodoropoulos sees the reason as conspiracy to maintain research and management funding, Pearce raises this specter only once and instead appears to ascribe the maddening lack of enthusiasm for his view to intellectual sloth and inertia, combined perhaps with widespread low-level xenophobia. Another hypothesis for the anemic support for his program is possible, one referring back to his unexamined conception of nature and his view that all local biodiversity anywhere is good. Perhaps, explicitly or even viscerally, most scientists, the public, and their policymakers simply do not agree with his conception of nature. Rather, they desire to maintain or at least partially restore ecosystems and the native species that evolved in and dominate them, they may be aware of enough of the impacts of non-native species to see them generally as an environmental threat to the nature they care about, and they have seen sufficient success in excluding or managing non-native species [14] that the failure to change course is reasoned rather than irrational or reactionary.

Possibly most New Zealanders prefer the beleaguered kiwis to the non-native predators that threaten them, don’t see the introduced birds that provide variety and color as adequate recompense,

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and maybe they are willing to make a big effort to save the natives [15]. If this is so, *The New Wild* can be seen not so much as a description of what invasions can and will do as an attempt to challenge such opinions and convince the public to favor the kind of nature Pearce so values. Will this attempt succeed? Only time will tell.

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Q & A

Melissa Bateson

Melissa Bateson is currently Professor of Ethology at Newcastle University. She grew up in an academic family in Cambridge, but migrated to Oxford for a BA in Zoology, followed by a DPhil with Alex Kacelnik studying the foraging decisions of European starlings. During a post-doctoral fellowship in Warren Meck's lab at Duke University in the USA, she attempted to learn some psychopharmacology. She returned to a Royal Society University Research Fellowship at Newcastle University, again studying decision-making. She has stayed at Newcastle, moving through the departments of psychology and biology, and is currently at the Institute of Neuroscience. Over the past decade she has become interested in emotion: what it is, how we can measure it in non-verbal subjects and latterly the developmental origins of low mood.

Who were your key early influences?

As a second-generation ethologist I obviously owe a huge amount to my father, Patrick Bateson. From the day I was born I was surrounded by biologists and during my childhood met many of the key figures in ethology of my father's generation (although at the time I completely failed to appreciate the privilege). My father always encouraged my interests in natural history and, when I was 14, he took me to East Africa to visit some of his students and colleagues working in national parks such as Amboseli and Serengetti. To me, this was the greatest adventure; I absolutely loved camping in remote places surrounded by animals that I had only previously seen in zoos or on the television. My father credits this early experience with inspiring me to become a biologist, but actually the influence was slightly less direct.

My teenage experiences of East Africa certainly made me desperate to return there. I went back to Tanzania first in my gap year before university to work as a research assistant on a baboon project in Mikumi National Park, and then again a couple of years later on an undergraduate expedition to study mate choice in African swallowtail butterflies on Pemba Island. It was this latter trip that really convinced me that I wanted to do research. On Pemba we were lucky to happen upon a behavioural ecologist's dream — a system that allowed us to conduct controlled experiments on wild animals. We devised the 'orgasmatron', a forked stake on which we could simultaneously present two, alternative, pinned, dead female butterflies to passing males. All we had to do was set up a choice and count the number of males courting each female. I can still remember the thrill of manually calculating binomial probabilities in the Landrover on the way home from field work, desperate to know what that day's experiment had told us. The data we collected resulted in my first scientific paper, and the experience convinced me that, much as I loved being in Africa and watching wild animals, what really excited me was the ability to test hypotheses *via* designed experiments. It was quite a relief to discover that I did have a passion for research, because until then I really hadn't been sure.

My undergraduate tutor at Oxford was Richard Dawkins. I learnt two things from Richard. Not surprisingly, he taught us to think clearly about natural selection, but equally importantly perhaps, he taught me to write. For our weekly tutorial meetings we had